Hurdles for Small Sat datasets in NOAA Operational Missions

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SENSOR CALIBRATION & TESTING FOR HOSTED SMALL SAT PAYLOADS

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Why is an operational agency interested in Small Sat systems

- Benefits
  - Smaller, faster to build, cheaper to build
  - Lower cost to space with small- and medium-lift launch vehicles, greater flexibility in launch schedules on demand
  - May have relatively low data rates for each unit
  - Rapid infusion of technology when subject to refresh of individual constellation units
  - And if you are in the Small Sat business you likely have your own favorite attribute, write them down and email them to me

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What are some of the hurdles for Small Sat missions

- The instruments are small
- They are quick to build, and fly in lower orbits
- There may be so many of them
- Data questions
- The instrument allow quick infusion of new technology
- Less pre-flight testing drives toward on-orbit testing to achieve performance

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NOAA operational algorithms are data source agnostic

- For an operational program, the intent is to operate Enterprise Algorithms for the products
  - Not necessarily applicable to imagery
- Enterprise algorithms already in operations for LEO (JPSS) and GEO (GOES-R) missions
- Enterprise algorithms are and will be applied to the LEO-Ring and GEO-Ring missions (ESA/EUMETSAT, Japanese, Chinese and Taiwanese, Indian etc. satellite devices)
  - Expect some adjustments in Enterprise algorithms to handle detailed, less significant performance differences in hardware from different countries

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But not without standards

- “Non-negotiable” data attributes
  - Latency
  - Resilience
  - Continuity
  - Interoperability
  - Performance (Radiometry, etc)
- Possibly negotiable
  - Open data access (by treaty/international agency agreements) with other national weather services
  - Value-added service providers

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What are the Hurdles I

- Small Sats are, well, small (wrt large sats)
  - Lower inertia
    - No solar array for power
    - More sensitive to microphonics
    - Do body mounted solar cells experience thermal snap when entering sunlight from eclipse
    - Geolocation challenges may resolve when observations aggregated to resolutions useful for Numerical Weather Prediction (NWP) models
  - Lower thermal inertia
    - Coupled to radiative environment of earth-atmosphere across orbit
    - Less cooling capability, maybe poorer sensor and detector body temperature control
  - Lower volumn
    - Little room for on-board calibration systems
    - Little room for thermal control devices
    - Lower safety-redundancy and shorter orbital lifetimes

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What are the Hurdles II

- Quick to build
  - May have significantly less laboratory characterization and calibration time
  - Ease of new technology may provide poorer reliability and quicker infant mortality
  - No long-lead parts, lower parts reliability when use ~ commercial parts
  - Smaller apertures, frequently more narrow swaths
- Lower orbits
  - Less lifetime each mission
  - Smaller swath for common acceptance angles

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What are the Hurdles III

- There may be so many of them
  - Small swaths drive to larger constellations for areal coverage
  - Integrated data set for NWP incorporation may require large constellations
  - Data set will be for constellation rather than for the individual unit where units have narrow swath
  - Are benefits in latency for NWP from Direct Broadcast with JPSS available to the constellation when individual units have unique performance capabilities
  - Low to no operational flexibility due to constellation management considerations

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What are the Hurdles IV

- Data
  - Integration of data from constellation at least as challenging to incorporate into NWP models as data set from a large mission
  - Stitching together spatial and radiometric data sets from constellation for performance models is uncommon skill
  - Enterprise Products mostly involve co-located measurements spread across the Vis/NIR/SWIR/TIR spectrum that do not fit an individual Small sat mission
    - Static fields such as surface type may be leveraged from other missions, but dynamic fields (clouds, surface reflectance) must be congruent to match current Enterprise Product performance
  - Continuity of input products needed to justify investment in putting products into operational models in first place
    - For 'short' lifetime units, how does Fleet Product Characterization handle resilience as units in fleet are exchanged over lifetime
  - New technology insertion into constellation may mean nuanced performance differences that need be manipulated with fleet characterization datasets

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What are the Hurdles V

- Performance
  - Laboratory testing, JPSS mission, typically 10-20% of on-orbit planned lifetime (2 years testing for say 7 years on orbit are JPSS metrics for VIIRS and CrIS)
  - Commercial missions for units headed to a constellation are building units one a week or faster
  - Individual more targeted missions headed to ~400 km orbits are in the 3 year lifetime range, and could get to 100 days testing with this metric. That seems doable
  - Typically would be without on-board full aperture calibration systems
    - May need rely on on-orbit vicarious approaches to maintain the calibration
  - These and following materials very familiar to the CALCON community but are being drawn together here for Small Sat community that may not be familiar with these resources

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Performance verification on-orbit Geolocation and Spectral

- Geolocation is easiest, as long as pointing controls are stable
- Spectral characterization is hardest (except for thermal interferometers)
  - If channels have high spectral co-registration, and adequate resolution, then Fraunhofer lines in solar spectrum or atmospheric absorption and emission lines may be used, even on a scan-by-scan basis (defer the ‘problem’ to the software – frequently the hardware-person’s common strategy)

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Performance Verification on-orbit Radiometry

- Radiometry may be complicated story
  - Is your sensor sensitive to polarization status of incoming radiation
  - RadCalNet may be the Gold Standard in VisNIR/SWIR
    - 10 nm TOA radiance every 10 min
  - Invariant Ground sites and monitored Ground sites
    - Desert sites (Libya Desert and Deep Convective Clouds are commonly used for moderate resolution missions; DOME C for ice fields
    - Monitored sites such as Railroad Playa and MOBY
  - Similarity, by comparison to other verified on-orbit resources in simultaneous overpasses
    - MODIS and VIIRS are commonly used in VisNIR, etc
      - Speaker refers to this as a CLARREO-type model

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Performance Verification on-orbit More on Radiometry

- CLARREO is a NASA proposal for Climate Monitoring and TRUTHS has similar purpose in the ESA Program
  - Concept is an orbit standard that may be used in comparison for less-well characterized space sensor in vicarious calibration
  - Small Sat operators are using similar technology to support on-orbit characterization for missions with low intrinsic calibration capability
  - We have heard mission operators using MODIS data because they cannot access VIIRS data
- We encourage VIIRS data as the future for these missions
  - VIIRS data available on AWS Big Data Project at:
  - https://www.noaa.gov/organization/information-technology/list-of-big-data-program-datasets#NESDIS.
  - Also may search for NOAA data at: https://data.noaa.gov/onestop/

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Some parting thoughts on unique small satellite considerations

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Special Considerations for Small Sat Leverage for Operational Data Products

- NOAA Enterprise Algorithms frequently use VIIRS products from several focal planes (Vis, NIR, SWIR and TIR)
  - Getting data from multiple band regimes, visual and thermal particularly, is challenge for Small Sat devices
  - Models include static and dynamic fields in product development
  - Take Surface Type and Surface Reflectance
    - Surface Type uses M1 – M11, except M6 and M9. This is covers VisNIR/SWIR
    - But Surface Type fundamentally is static field (monthly) so analysis for a Small Sat product may leverage VIIRS, etc, Surface Type products in their development
    - Surface Reflectance (typically at multiple wavelengths) would not need as many bands (with clean cloud mask), but it is dynamic and will require ~ congruent observations
    - NPP and N-20 same orbit plane, half orbit apart. These are not close enough to use one measurement for analysis of other data for most dynamic fields.
  - Use of existing operational fields may reduce number of bands required for products to ease band selection considerations for Small Sat
    - Need review each product specifically to identify leverage opportunities, but it may be difficult to converge an appropriate measurement set for many products

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